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Injection moulding device

The present invention relates to an injection moulding device for foamable materials comprising a plasticizing means including, in succession, a feed section for receiving therein a material to be plasticized, a conversion zone for plasticizing the material and an ejection zone for discharging the plasticized and compacted material, further comprising an apportioning means for apportioning a foaming agent to the plasticized and compacted material, a mixer for homogeneously mixing the foaming agent and the plasticized and compacted material, and a pressure chamber for dissolving the admixed foaming agent in the material, the material being adapted to be supplied from said pressure chamber via a throttle means to a die.

Such an injection moulding device is known in practice. The feed section of the plasticizing means has supplied thereto via a hopper especially a polymer in the form of a granular material or powder, said polymer being used as a plasticizable material. Subsequent to the feed section, the material is plasticized and compacted in the conversion zone of the injection moulding device and, finally, it is discharged in the ejection zone. In conventional injection moulding devices, the material can be discharged directly to the die via a throttle or the like.

If the material used is, however, a foamable material, the plasticized and compacted material must have added thereto a foaming agent with the aid of an apportioning means. The amount of the foaming agent is dosed such that, after mixing of the foaming agent and the material in a mixer, the foaming agent is dissolved in the material in a pressure chamber following said mixer.

Subsequently, a certain amount of material having the foaming agent dissolved therein is supplied via a throttle means to the die so as to produce a final product. In the throttle means and in the die, nucleus formation takes place in the material, an aggregation of at least a certain number of molecules occurring at these locations of nucleus formation and bubbles forming from the foaming agent in accordance with the decrease in pressure and before the material hardens. In the case of a microcellular material these bubbles or cells have a diameter of a few micrometers up to 50 or even 100 micrometers. In the case of sub-microcellular bubbles, the diameters of said bubbles are even smaller than that. These

bubbles should be distributed in the material as homogeneously as possible and with almost identical diameters.

In the injection moulding device known in practice the foaming agent is apportioned in the plasticizing means after plasticization of the material. The plasticizing means may include the mixer between the conversion zone and the ejection zone so that also the mixing of the foaming agent and of the material takes place within the plasticizing means. In the known injection moulding device, the ejection zone is followed by a pressure chamber within the plasticizing means, the pressure and temperature conditions prevailing in said pressure chamber being of such a nature that the foaming agent will be dissolved in the material.

Subsequently, the material having the foaming agent dissolved therein can be supplied from the pressure chamber to the die via the throttle means.

It is the object of the present invention to improve an injection moulding device of the type mentioned at the start in such a way that the pressure chamber can variably be defined in a simple manner and that material can easily be fed into and discharged from said pressure chamber.

In connection with the features of the generic clause of claim 1, this object is achieved by the feature that the pressure chamber is formed between plungers which are adapted to be axially displaced, especially independently of one another, in the interior of a pressure cylinder.

A plasticizing means having a simple structural design and comprising all zones can be defined by an extruder.

In order to provide the possibility of subsequently retrofitting a plasticizing means and an extruder, respectively, the apportioning means and/or the mixer and/or the pressure chamber can define a module which is adapted to be secured to a discharge end of the extruder via a flange. This module is preferably compatible with all plasticizing means and injection moulding devices.

In order to permit a mixing operation independently of the extruder, the mixer can be implemented separately from the plasticizing means and it can include a mixing screw which is rotatably supported in a substantially cylindrical mixing chamber.

In order to obtain in the pressure chamber a pressure independently of the pressure in the mixer, the mixing chamber can be connected to the pressure cylinder via a supply bore which is adapted to be closed by at least one plunger. The mixture of material and foaming agent is supplied via this supply bore to the pressure chamber, where, when the supply bore has been closed, it can be pressurized in a suitable manner prior to discharge into the die.

A compact module will e.g. be obtained when the longitudinal axes of the mixing screw and of the pressure cylinder extend substantially parallel to one another.

In order to open, especially after the closing of the supply bore, the pressure chamber first relative to the throttle means and the die, respectively, the pressure cylinder can be connected to the throttle means displaced relative to the supply bore when seen in the direction of the longitudinal axis of the pressure cylinder.

A simple embodiment for such a throttle means is imaginable in the case of which the throttle means is substantially formed by an outlet bore which opens into the interior of the pressure cylinder.

In order to permit a simple adaptation to dies of different sizes and/or to different pressures desired in the pressure chamber, the volume of the pressure chamber can be varied by the adjustable distance between the plungers. A simple cycle for the plungers for producing a number of moulded parts is realizable when the plungers are adapted to be displaced between an admitting position connecting the pressure chamber to the supply bore and a discharge position connecting the pressure chamber to the outlet bore. At the admitting position, the pressure chamber has supplied thereto material with foaming agent in desired amounts and under the pressure desired. By adjusting the plungers, the pressure chamber is displaced; in so doing, the pressure in the pressure chamber can be increased, decreased or maintained, as desired. When the two plungers have been displaced according to requirements, a communication between the pressure chamber and the outlet bore is

established, and the material having the foaming agent dissolved therein is transferred to the die via the throttle.

Using only the outlet bore as a throttle, a predetermined pressure relief rate can be obtained when, at the discharge position, the outlet bore can variably be closed by a plunger acting as a throttle plunger for determining the pressure relief rate.

In contrast to the known prior art, where the injection rate into the die is determined by displacing the extruder screw in the direction of the outlet end of the extruder, one embodiment of the present invention is so conceived that, at the discharge position of the plungers, one plunger, acting as a pressure plunger, can be moved towards the throttle plunger in a controlled manner so as to determine the injection rate into the die.

In order to permit also two-component injection moulding, at least one plunger can be provided with a transverse bore for feeding ungassed, plasticized material to the outlet bore.

Such a transverse bore can be realized in a simple manner when, at a through-position of the plunger, the transverse bore connects a bypass bore to the outlet bore, said bypass bore communicating with the plasticizing means. The bypass bore permits a direct transport of material from the plasticizing means to the throttle means, without the material in question passing the mixer and the pressure chamber. In order to prevent in this connection a supply of material to the pressure chamber also when the mixer continues to operate, the supply bore can be closed by a plunger at the through-position.

One embodiment according to the present invention offers the possibility of supplying a defined amount of ungassed material from the plasticizing means via the transverse bore to the throttle means, the respective amount of material being determinable in that an extruder antechamber is formed in the extruder between the discharge end and an extruder screw. When the extruder screw is axially displaced towards the extruder antechamber, the material contained in said antechamber will be supplied to the throttle means via the bypass bore and the transverse bore.

For connecting the plasticizing means and the extruder, respectively, to the mixer and the transverse bore in a simple manner, the extruder can be followed by a discharge bore

branching into a mixer bore, which extends towards the mixer, and the bypass bore.

In to permit the foaming agent to be fed to the material in a simple manner prior to mixing in the mixer, the foaming agent can be adapted to be fed to the mixer bore by the apportioning means. By carrying out the apportioning step in the mixer bore, gassing can simultaneously take place in a narrow cross-section.

In order to determine the desired amount of foaming agent for obtaining a microcellular or sub-microcellular material, the apportioning of the foaming agent can be controlled in dependence upon a feed rate of the extruder screw.

In accordance with an advantageous embodiment, a desired diffusion pressure can be maintained in the variable pressure chamber, when said pressure chamber is being filled with material, in that, depending on the desired diffusion pressure, at least one plunger is moved away from the other plunger, when said pressure chamber is being filled with material.

According to the present invention it is also possible to maintain the diffusion pressure in the material in that both plungers are displaced synchronously in the direction of the throttle means when the pressure chamber has been filled.

For a simple adaptation of conventional plasticizing means or extruders to an injection moulding process in which at least microcellular materials are processed, the present invention is so conceived that the module can be a prefabricated module unit in the case of which all subunits, such as mixer, apportioning means, pressure cylinder with plungers and throttle means, are already assembled in advance.

Reference should here additionally be made to the fact that the foaming agent can, in a manner known per se, be a chemical or physical foaming agent, CO₂ or N₂ being preferred as physical foaming agents.

In the following, an advantageous embodiment of the present invention will be explained in detail making reference to the figure according to the drawing, in which:

Fig. 1 shows a section through an injection moulding device according to the present invention comprising a module secured to a plasticizing means via a flange.

Fig. 1 shows a section through an embodiment of an injection moulding device 1 according to the present invention. This injection moulding device includes a plasticizing means 3 in the form of an extruder comprising an extruder cylinder 41 and an extruder screw 31 rotatably supported therein. The plasticizing means 3 includes a feed section 4 only part of which is shown and within which material 2 in the form of granular material or in the form of a powder can be fed by means of a hopper, not shown. The feed section 4 is followed by a conversion zone 5 in which the material supplied is plasticized and compacted. This conversion zone is followed by the ejection zone 6 in which the plasticized and compacted material 2 can be transferred via a discharge end 30 of the plasticizing means (extruder) 3 to a module 16 secured thereto via a flange 35.

The module 16 is adapted to be connected to any conventional extruder 3 so that the extruder in question can be converted into an injection moulding device 1 for producing micro-cellular material.

The module 16 comprises an apportioning means 7 (only part of which is shown), a mixer 9, a pressure chamber 10 and a throttle means 11. The latter is followed by a conventional injection-moulding die 12.

The apportioning means 7 serves to apportion a foaming agent, especially a physical foaming agent, such as CO₂ or N₂. The apportioning takes place after a point where a discharge bore 33 branches into a mixer bore 34 and a bypass bore 29. The discharge bore 33 extends from the discharge end 30 of the extruder 3 into the module 16; according to Fig. 1, the mixer bore 34 branches off from the discharge bore 33 at right angles to the left. The apportioning means 7 ends with a gas discharge end 36 in said mixer bore 34.

The bypass bore 29 first extends in the direction of the discharge bore 33 and then, displaced parallel to the right relative to said discharge bore 33, towards the pressure chamber 10.

The mixer bore 34 opens towards the mixer 9, which is defined by a mixing screw 18 rotatably supported in a mixing chamber 17. Neither the support in question nor a drive for the mixing screw 18 are shown for the sake of clarity.

In order to increase the mixing effect of the mixer 9, positioning pins 39 are supported in the module 16 such that they are adapted to be secured in position perpendicularly to the longitudinal axis 20 of the mixing screw 18. In opposed relationship with said positioning pins 39, a supply bore 19 is formed in said module 16, one end of said supply bore 19 opening into the mixing chamber 17 and the other end into the pressure chamber 10.

The pressure chamber 10 is formed in the interior 22 of a pressure cylinder 13 and the sides of said pressure chamber 10 are delimited by plungers 14, 15. A volume of the pressure chamber 10 can be varied by varying a distance 24 between said plungers 14, 15.

In Fig. 1, the plunger 15 is arranged as a pressure plunger in the admitting position 25 in which the supply bore 19 is open towards the pressure chamber 10. In the case of a corresponding arrangement of the plunger 14 at position 25, the end face of said plunger 14 extends along the broken line.

The pressure chamber 10 and the pressure cylinder 13 are arranged such that their longitudinal axis 21 is arranged parallel to the longitudinal axis 20 of the mixing screw 18, both plungers 14, 15 being adapted to be moved independently of one another in directions 37, 38.

In the discharge position 26, the pressure plunger 15 is arranged at position 15, 26, which is indicated by a broken line, and the plunger 14 is arranged as throttle plunger at the depicted outlet position 26 at which an outlet bore 23, which constitutes part of the throttle means 11, is exposed. The outlet bore 23 is arranged such that it is located in opposed relationship with the supply bore 19 and displaced parallel to said supply bore 19 in the direction of the longitudinal axis 21.

The throttle plunger 14 can be arranged such that it partially covers the outlet bore 23, whereby a pressure relief rate within the pressure chamber 10 is determined. When the throttle plunger 14 is at the outlet position 26, the pressure plunger 15 can be advanced

from the outlet position, which is indicated by broken lines, in the direction of the throttle plunger so as to feed the material, which is contained in the pressure chamber 10 and in which the foaming agent is dissolved, gradually via the outlet bore 23 in the direction of the die 12.

The throttle plunger 14 has arranged therein a transverse bore 27 which, in a through-position 28, cf. the representation of the transverse bore 27 indicated by a broken line, connects the outlet bore 23 to the bypass bore 29. When the throttle plunger 14 is at the through-position 28, ungassed material 2 is supplied from the extruder 3 via the bypass bore 29 and the transverse bore 27 to the outlet bore 23 and, consequently, the throttle means 11 and subsequently to the die 12.

In the following, the mode of operation of the injection moulding device according to the present invention will be described briefly.

The method steps dosing the gas, distributing/mixing the gas and the material or dissolving the gas in the material, injection and expansion are executed in module 16. This module 16 can be secured to a conventional plasticizing means (extruder) 3 via a flange.

The extruder screw 31 feeds plasticized material via a system of bores to the mixer 9, which is preferably driven. In said mixer 9 the foaming agent apportioned with the aid of the apportioning means 7 is admixed. The plungers 14, 15 are at the admitting position 25, and the supply bore 19 in the interior 22 of the pressure chamber 10 is exposed.

The gassed and mixed material enters the pressure chamber 10 between the two plungers 14, 15, which have been moved towards each other, one of the two plungers carrying out a decelerated backward movement towards the outlet bore 23 in accordance with the desired diffusion pressure. The admixed foaming agent is dissolved under pressure in the plasticized material.

Subsequently, both plungers move in common towards the outlet bore 23 while maintaining the desired diffusion pressure, and, when they have reached the outlet bore, the material begins to expand into the die 12; in the course of this process, the formation of foam begins. The relative overlap of the throttle plunger 14 and the outlet bore 23 determines the

pressure relief rate and the movement of the pressure plunger 15 determines the injection rate and the injection pressure of the plasticized material. The throttle plunger 14, together with the outlet bore 23, serves as a controlled throttle means 11. The pressure plunger 15 serves as an injection cylinder for filling the die 12 and produces the respective dwell pressure.

When the dwell pressure has terminated, both plungers 14, 15 move back in the direction of the supply bore 19 and the cycle begins once more.

According to the present invention, the material and the foaming agent are mixed independently of the extruder screw. In addition, the diffusion pressure is independent of the pressure in the mixer and of the pressure in the extruder screw, since said diffusion pressure is determined by the volume of the pressure chamber 10. Two-component injection moulding can be executed, said two-component injection moulding comprising e.g. the steps of supplying first an ungasged material via the transverse bore 27 to the die 12 and then a gassed material via mixer 9, pressure chamber 10 and outlet bore 23 to said die 12. Exact dosage of the foaming agent with the aid of the apportioning means 7 is carried out in dependence upon the feed rate 40 of the extruder 3, the gassing being expediently carried out in a narrow cross-section, i.e. in the mixer bore 34.

Due to the throttle means 11 according to the present invention, a predetermined relief rate without any physically existing throttle is obtained, the throttling effect being produced by the co-operation of the throttle plunger 14 and the outlet bore 23.

Furthermore, a mixing process, which is independent of the extruder screw, is obtained due to the additional mixer 9 which, in connection with the pressure chamber, simultaneously guarantees that the material which is supplied first to the pressure chamber 10 can also be supplied first to the die 12 via the throttle means 11.